other worms with increased ascaroside production, a type of response not seen in hermaphrodites [16]. Future studies in this area will likely yield some fascinating chemical biology of sex-specific secretions.

Based on the data presented in the study of Noble *et al.* [2], we can postulate that the male–male mating phenotype likely evolved before the advent of hermaphroditism in *C. elegans*. In future studies, it would be interesting to see whether male–female species containing a mutation within the same genetic locus display a similar phenotype. Additionally, chemical analysis of the 'secretome' from the excretory pore of the different isolates may result in the discovery of novel signaling molecules and provide insights into the evolution of mating systems.

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Multisensory Perception: The Building of Flavor Representations

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http://dx.doi.org/10.1016/j.cub.2015.09.009

The perceptual construct of flavor is built on the basis of interactions between taste and odor processing. Recent work sheds new light on how intimately coupled these two senses are, and call into question conventional views about the 'unisensory' processing of odors.

Our perceptual view of the world is built on a multisensory foundation. This concept of perception as a multisensory construct is perhaps no more evident than in our sense of flavor — which is ultimately built upon both gustatory (taste) and olfactory inputs. The inherently multisensory nature of flavor perception is best illustrated when we are suffering from nasal congestion (such as from a respiratory virus) and olfactory input is greatly attenuated: under these circumstances, our sense of flavor is often reduced to the fairly rudimentary submodalities of taste alone (salt, sweet, sour, bitter and umami). A paper in this issue of *Current Biology* [1] sheds important light on the nature of the conversations between gustatory and olfactory brain regions that ultimately give rise to flavor perception.

Although the multisensory character of our perceptual reality seems self-evident, neuroscience continues to explore the brain circuits and processes that give rise to our unified and coherent gestalt view of our world [2]. The 'laundry list' of brain areas considered multisensory continues to grow, with findings that inspired the provocatively titled review "Is neocortex essentially multisensory?" [3]. Although the debate surrounding this question continues, influences from other sensory modalities have been found in areas traditionally considered the dominion of a single sense — such as primary visual, auditory and somatosensory cortices [4–12]. The presence of such influences has revolutionized the way in which we think about sensory function, by highlighting that the traditional hierarchical view of unisensory processing followed by multisensory convergence and integration is only one part of the story.

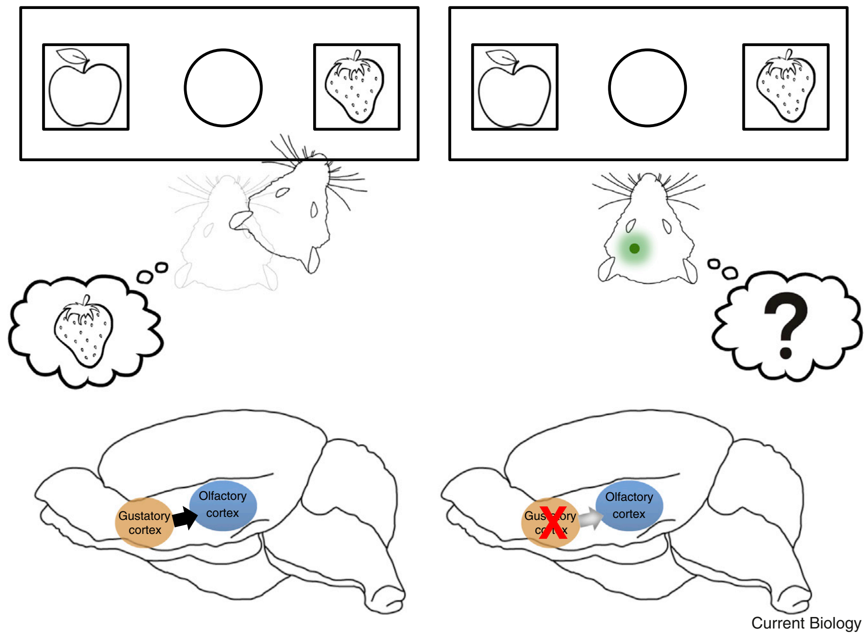

Figure 1. The importance of gustatory cortex in olfactory perception.
The top part of the figure depicts a schematic representation of an odor preference paradigm, in which rats learn to associate a specific odor (in this case strawberry, as opposed to apple) with a sweet reward. As shown in [1] and depicted in the lower panel, the presence of activity in gustatory cortex (insula) is necessary for expressing preference behavior, via its direct and indirect influences over olfactory processing in piriform (olfactory) cortex. As shown in the right panels, when gustatory cortex is optogenetically silenced, learned odor preference behavior is impaired.

Returning to the specific questions surrounding flavor, there has been surprisingly little work exploring the brain bases of olfactory and gustatory interactions — interactions necessary to create the truly integrated percept of flavor that we experience. Although both direct and indirect connections have long been known to exist between gustatory and olfactory cortices, the functional nature of these projections has not been well studied [13]. In their paper in this issue, Maier, Katz and colleagues [1] explore the functional dialogue between these cortical regions, using a powerful combination of electrophysiological, optogenetic, and behavioral methods. Their work greatly extends our knowledge of gustatory–olfactory interactions in several dimensions. First, the authors demonstrate, using optogenetic inactivation of gustatory cortex, that responses in olfactory cortical neurons are strongly influenced by inputs from gustatory cortex. Second, they go on to show that these influences can take place in the absence of gustatory stimulation, a provocative finding that suggests that normal olfactory function is continually under dynamic control from gustatory cortex. Finally, they show that gustatory inputs to olfactory cortex play an essential role in olfactory behavior, by demonstrating that inactivation of gustatory cortex eliminates the ability of rats to express a previously learned odor preference (Figure 1). The collective findings of the work are aptly summarized by a simple statement in the paper: "gustatory cortex is involved in olfactory perception".

Along with expanding our understanding of gustatory–olfactory interactions and their role in assembling the perceptual construct of flavor, the work also highlights the power of optogenetic approaches for addressing circuit-related questions in multisensory research. As it by definition necessitates the convergence of information from different sensory domains, multisensory processing is centrally dependent upon circuit level computations, and optogenetics provide a powerful means to bring a reversible 'scalpel' to dissect out causal contributions to the construction of a multisensory percept. Several recent studies point to these possibilities. In the first of these [14], examination of a region of visual–tactile convergence in the mouse found parvalbumin-expressing interneurons to be critical for the capacity of nearby pyramidal neurons to integrate visual and tactile information. In the second [15], carried out in the fruit fly, optogenetic manipulations were used to illustrate the cellular mechanisms by which visual motion perception is enhanced in the presence of ecologically important odors. These studies provide but a glimpse of the utility and power of these methods, and will likely usher in a new era for multisensory research with a shift from more phenomenologically oriented studies toward more mechanistically oriented studies.

As in all good science, the provocative experiments carried out by Maier, Katz and colleagues [1] raise as many new questions as they answer. For example, are certain elements of olfactory processing and perception more or less influenced by gustatory cortex? One can envision an experiential process that couples specific tastes and specific odors for commonly encountered flavors, and these experiences may shape the construction of the connectivity patterns between gustatory and olfactory cortex. Furthermore, the experiments carried out examine just one direction of information flow — from gustatory to olfactory cortex. Does olfactory cortex have a similar capacity to change the nature of taste processing in gustatory cortex? An overarching question is the specificity of gustatory cortex in modulating olfactory function. We know from our own anecdotal observations that flavor perception can be strongly modulated by higher-order cognitive influences. Simply think about how expectancy can accentuate (or dampen) the flavor experience. Hence, the gustatory–olfactory interactions so elegantly demonstrated in this new work are likely to be a component of a much broader network of interactions that ultimately result in our perception of flavor. Indeed, the long temporal lags seen in the influences between the two cortical domains suggest that the connections between them are far from direct, and are thus likely passing through other processing stages before having their ultimate effects on flavor perception.

Perhaps the most thought-provoking element of this study is its implications for sensory function more broadly defined. As highlighted earlier, functional interactions between regions of early sensory cortex are being increasingly demonstrated. Much of this work has been predicated on the idea that *stimulation* in one sensory modality can change the processing of stimuli in another sense. However, these functional interactions almost undoubtedly exist even in the absence of stimulation. Indeed, if the connectivity is in place to support interactions in the presence of stimulation, it must be present at all times. These results provide an intriguing framework within which to view sensory function — one in which sensory processing both within and across the different modalities is dynamically interconnected at all times — regardless of whether overt stimulation is happening or not. Perhaps the entire neocortex is indeed multisensory.

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Circannual Biology: The Double Life of the Seasonal Thyrotroph

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Endogenous long-term timing is a key component of seasonality. Where and how are such rhythms generated? Recent findings pointed to the pituitary *pars tuberalis*, already implicated in photoperiod responsiveness. Now, a new study provides mechanistic insights which support this hypothesis.

Procrastination is a luxury most organisms can ill afford. If you are a squirrel or a groundhog you had better be prepared for winter food scarcity if you do not want to end up like La Fontaine’s cicada! Anticipation is the key. In order to

